CHANGES IN NITRATE-NITROGEN CONCENTRATION IN SUGAR BEET PETIOLES AS INFLUENCED BY IRRIGATION AND FERTILIZER PRACTICES[1, 2]

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INTRODUCTION

Sugar beets must be properly irrigated and fertilized to maximize sugar production. Both yield and sugar content can be materially altered by water or fertilizer deficiency or excesses (4, 5). Farm operators must carefully manage fertilization and irrigation to obtain the greatest net return from sugar beets.

Of the common fertilizer elements, nitrogen has the greatest effect on sugar beet yield and sugar content (1, 2). Inadequate nitrogen, either residual or applied, limits root yield. On the other hand, excess nitrogen stimulates top growth and reduces root sugar percentage. An adequate soil or tissue test is needed to properly manage nitrogen fertilization of sugar beets. The purpose of this study was to evaluate procedures for determining the NO_3-N content of sugar beet petioles at all plant growth stages and to relate values obtained to irrigation practices and nitrogen fertilizer requirements.

MATERIALS AND METHODS

A field experiment was conducted in 1966 on a Portneuf silt loam near Twin Falls, Idaho. Four replications of randomized soil moisture plots, split for nitrogen rates, were used. Each replication contained 8 plots.

Two soil moisture or irrigation treatments were used. The M_1 treatment was irrigated 12 hours per set when the soil moisture tension at the 18-inch depth approached 0.65 atm, except for the first and second irrigation. The first irrigation of 6 hours was made when the tension reached 0.45 atm and the second of 8 hours at 0.55 atm tension. The M_2 treatment was irrigated at the same time as the M_1 except the duration of the first irrigation was 12 hours and that of all others was 24 hours.

Four rates of nitrogen that were some fraction or multiple of an optimum rate, F_o, were used. The rates were 0.5 F_o, F_o, 1.5 F_o, and 2 F_o. The optimum nitrogen fertilization rate was determined by the difference between the estimated amount needed for a 30-ton root yield (280 lbs of N/A) and the residual nitrogen that would be available for plant growth. The residual soil nitrogen that would become available for plant growth during the

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growing season was estimated by determining the water-extractable NO_3-N content of the soil after 3 weeks' incubation at 30° C.

Phosphorus was uniformly applied March 23 at a rate of 55 pounds of P per acre. The experimental area was then disked, plowed to a depth of 8 inches and a seedbed prepared. The sugar beets were first planted March 30, but froze April 18. They were replanted April 23 and thinned to approximately a 9-inch spacing early in June. Ammonium nitrate was applied June 17 as a side dressing just below and to the side of the irrigation furrow to minimize leaching. All plots were irrigated June 28, using every furrow.

Beet petiole samples were taken from each plot at regular intervals throughout the season for NO_3-N analysis. Forty petioles were taken at random from each plot by selecting a young, fully mature leaf from each plant sampled. Samples were taken during the late morning hours at each sampling date. The petioles were brought into the laboratory and cut in half. Twenty leaf ends and twenty beet ends of these petioles, selected at random, were used for a quick-test for NO_3-N content using fresh tissue. The remaining halves were cut into 1/8-inch sections and mixed. Then, one-half of this sample was oven-dried at 50° C and the other half was freeze-dried. The dried samples were ground to a 40-mesh size and subsampled for NO_3-N analysis.

The NO_3-N content of sugar beet petioles was determined by two different methods. The quick-test on the fresh tissue reported in this experiment was made by a commercial fertilizer company using methods normally used in their tissue testing program. The nitrate concentrations of the oven- and freeze-dried samples were determined by the phenoldisulfonic acid method (3) using a water extract of the beet petioles.

RESULTS AND DISCUSSION

A comparison of the NO_3-N level as indicated by the quick-test on the fresh petioles and the laboratory analysis on the ground tissue on individual sampling dates showed a greater variation on July 8 and July 22 (Figure 1). The standard error of the quick-test measurement was 16.6 on July 8 and 23.0 on July 22, as compared with 5.8 on August 5, 4.4 on August 19, and 6.9 on September 2. Variations occurred in the slope and intercept of the regression line on the different dates of sampling. This variation could have been caused by the differences in the petiole tissue or in the sampling techniques used by the quick-test on the different dates sampled. If the three high F points on July 22 are not used, the regression equation is $Y = 1.7 + 0.00574\ N$. The quick-test method as used appears to be suitable for roughly determining if a field of beets had low, medium, or high levels of nitrogen available for plant growth. A nonrepresentative fresh tissue sample is the most probable cause of the variability encountered in the quick-test. Additional subsampling may reduce this variability. A composite graph of all quick-test and laboratory data is presented in Figure 2. A technique that has the speed of the quick-test and the accuracy of the detailed laboratory analysis is needed for determining the NO_3-N level.

Small variations in the NO_3-N concentration in the petioles occurred between oven-dried and freeze-dried samples (Table 1). In general, the NO_3-N values for the oven-dried samples were higher than for the freeze-dried

samples. This difference could have been due to the lower level of moisture in the oven-dried samples. From the results of this work, it can be concluded that no significant loss of NO_3-N, or carbonaceous material, can be expected in the oven-drying process if the oven temperature is kept near 50° C.

The NO_3-N level of the sugar beet petioles varied with stage of plant growth, level of applied nitrogen fertilizer, and to a limited extent with the moisture level as shown in Figures 3 and 4. The NO_3-N concentration in the petioles increased during the early plant growth stages at all nitrogen application levels and declined rapidly after about July 8 as the plant growth increased. The NO_3-N concentration at any selected plant growth stage was directly related to the applied nitrogen level. Excessive irrigation caused a more rapid decrease in the NO_3-N in the petioles on the 0.5 F_o and F_o nitrogen treatments. There was very little difference in NO_3-N content between irrigation levels on the 1.5 F_o and 2 F_o nitrogen treatments.

The generally accepted critical low range for NO_3-N, based on water-extractable nitrates from mature petioles, is between 1000 and 2000 ppm. Also, if the NO_3-N concentration drops below 1000 ppm for any appreciable time before midseason, root and sugar yield will be reduced. The available nitrogen supply of the soil should be depleted about 4 to 6 weeks before harvest or about August 20 in this area. The data in Figures 3 and 4 show that the NO_3-N concentration on the 0.5 F_o treatment dropped below 1000 ppm early in August; hence, a reduction in yield would have been expected according to previous studies. The root yield on the 0.5 Fo treatment was about 2 tons per acre less than on the 1.5 F_o and 2 F_o. Therefore, maintaining the NO_3-N level above 1000 ppm until the latter part of August would appear to eliminate nitrogen as a limiting factor in sugar beet yields, as was evidenced by the nitrogen level on the 1.5 F_o and 2 F_o treatments.

There was a slight depression in the percentage of sugar in the roots at the highest level of applied nitrogen (Table 2). However, this lower sugar content was offset by an increase in yield (Table 3), so that sugar production was about the same on all but the low nitrogen treatment (Table 4).

Predicting the nitrogen level in the petioles during the latter part of August from petiole analyses early in the season would be the goal of a tissue testing program. This would enable the producer to apply additional nitrogen fertilizer, if needed, for maximum production of a high-quality beet root.

Preliminary analysis of the data indicates that after the nitrate-nitrogen had reached a peak on all treatments, the decline in NO_3-N followed a definite functional relationship. The rate of decrease in NO_3-N in the petioles was proportional to the concentration in the petioles as indicated by equation 1:

$$\frac{dN}{dt} = -C_1 N \qquad 1$$

where N is the NO_3-N concentration in the petioles, t is time, and C_1 is a constant for a given treatment. Integration of equation 1 with the peak concentration of nitrogen at t = 0 used as the integration constant results in the following equation:

$$N = N_o \exp(-C_1 t) \qquad 2$$

where N_o is the peak concentration of NO_3-N, t is the time after the peak (t_o) occurs, and C_1 is a constant which can be evaluated by determining the NO_3-N content at two dates any time after the peak occurs.

Equation 2 is evaluated in Figures 3 and 4. The solid lines after July 8 represent equation 2 where N_o is the NO_3-N on July 8, and C_1 was determined by the change in NO_3-N between July 8 and July 22. The solid lines prior to July 8 were merely fitted to the points. The dashed lines represent the estimated increase in NO_3-N from July 1 to July 8. The data presented in Figures 3 and 4 indicate that equation 2 adequately predicts the NO_3-N in the sugar beet petiole for all practical purposes. Therefore, if NO_3-N content of the petioles can be determined on two dates after the peak has been reached, the NO_3-N concentration during the remainder of the season can be predicted to determine the adequacy or inadequacy of available nitrogen.

A functional relationship between NO_3-N early in the season and its rate of change with time is needed to determine the need for adding additional nitrogen. Other factors will also probably need to be considered. For example, if the beets had already been sidedressed, as was done in this study, and the root system was not utilizing this nitrogen, the nitrate content of the petioles might not reflect the available soil nitrogen. If nitrogen had been mixed in the upper layers of the soil earlier in the season, then a functional relationship based on the NO_3-N concentration of the petioles early in the season might permit predicting the adequacy of nitrogen during the remainder of the season for optimum sugar production. The NO_3-N content at two dates with an interval of one or two weeks between sampling dates would probably be needed for this purpose.

SUMMARY AND CONCLUSIONS

The results of this experiment indicate that the level of nitrogen to be applied for maximum sugar production can be estimated from a reliable soil or tissue test. The soil test, performed early in the growing season, would be preferred to the tissue test so that nitrogen could be applied before planting. Tissue testing of the beet petioles can be used to supplement a soil test in predicting the adequacy of nitrogen during the growing season. By the use of an adequate soil nitrogen test and the mathematical approach discussed in this paper for predicting the change in NO_3-N in the petiole, maximum production of a high-quality beet root can be achieved.

Table 1. Effect of drying methods on the NO_3-N concentration in sugar beet petioles.

Fertilizer treatment		ppm NO_3-N in petioles			
		24 June		2 September	
		Freeze-dry*	Oven-dry**	Freeze-dry*	Oven-dry**
M_1	0.5 F_o	7620	7550	40	220
	F_o	9670	10350	200	360
	1.5 F_o	8490	9330	1830	1310
	2 F_o	10150	10800	2140	1620
Avg		8980	9510	1050	880
M_2	0.5 F_o	8960	9550	110	240
	F_o	9540	10460	310	340
	1.5 F_o	9780	9810	680	750
	2 F_o	11030	10640	2010	2050
Avg		9830	10110	780	850

*Dried until the samples reached room temperature.
**Dried at a temperature of 50° C.

Table 2. Effect of nitrogen and moisture level on the sugar content of beet roots.

Fertilizer treatment	Sugar content at moisture levels		
	M_1	M_2	Average
	%	%	%
0.5 F_o	17.3	17.3	17.3
F_o	17.4	17.2	17.3
1.5 F_o	17.3	17.0	17.2
2 F_o	16.9	16.6	16.8
Average	17.2	17.0	17.1

Table 3. Effect of nitrogen and moisture level on the yield of sugar beet roots.

Fertilizer treatment	Yields at Moisture Levels		Average
	M_1	M_2	
	tons/acre	tons/acre	tons/acre
0.5 F_o	22.5	24.3	23.4
F_o	22.5	24.2	24.9
1.5 F_o	24.6	25.7	25.2
2 F_o	24.9	26.6	25.8
Average	24.4	25.2	24.8

Table 4. Effect of nitrogen and moisture level on the yield of sugar.

Fertilizer treatment	Sugar yields at moisture levels		Average
	M_1	M_2	
	tons/acre	tons/acre	tons/acre
0.5 F_o	3.88	4.21	4.05
F_o	4.43	4.17	4.30
1.5 F_o	4.24	4.37	4.31
2 F_o	4.22	4.40	4.31
Average	4.19	4.29	4.24

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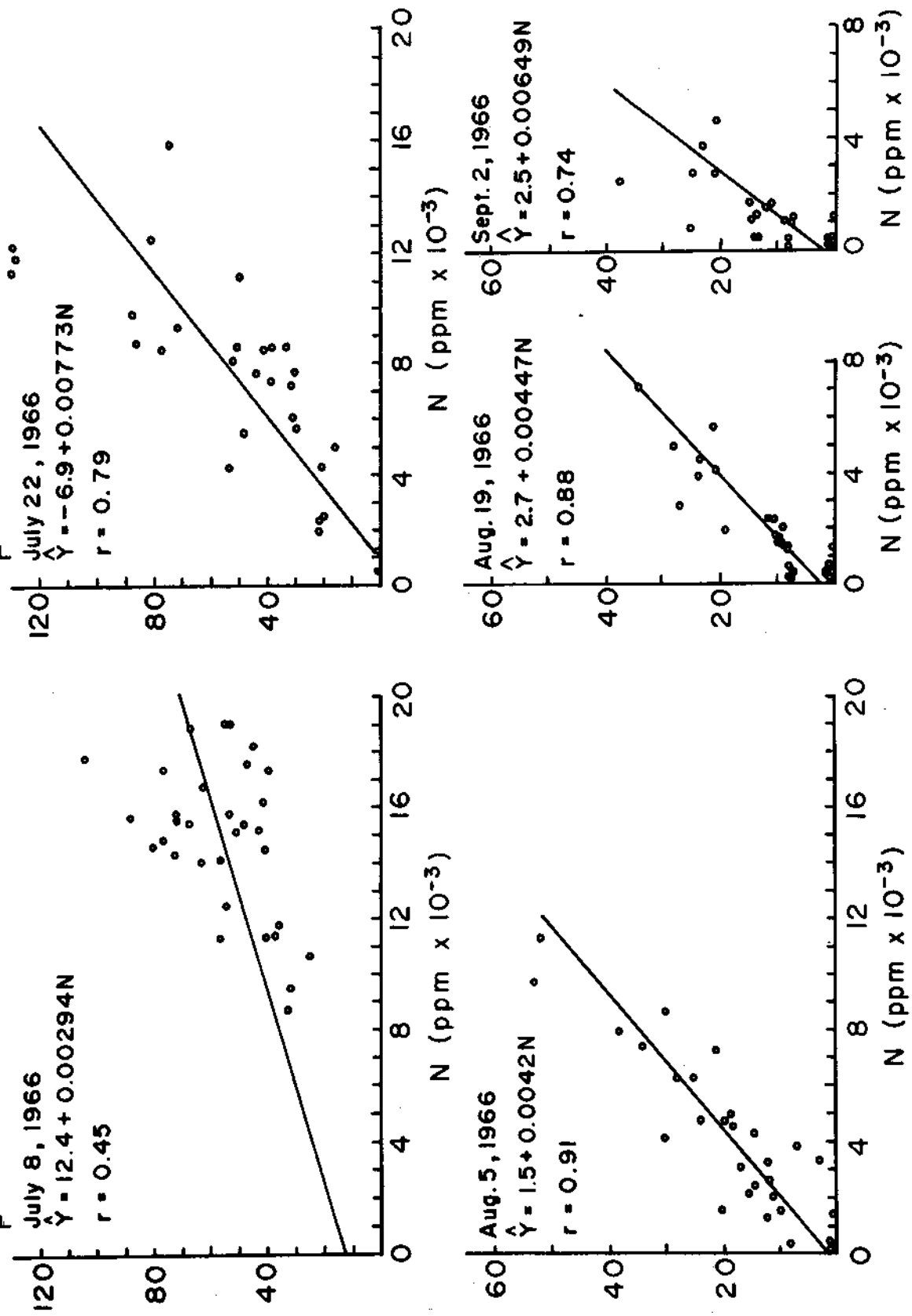


Figure 1. Comparison between a quick-test on the fresh tissue (F) and a laboratory analysis on the dried, ground petioles for NO_3-N(N) concentration in sugar beet petioles at various sampling dates.

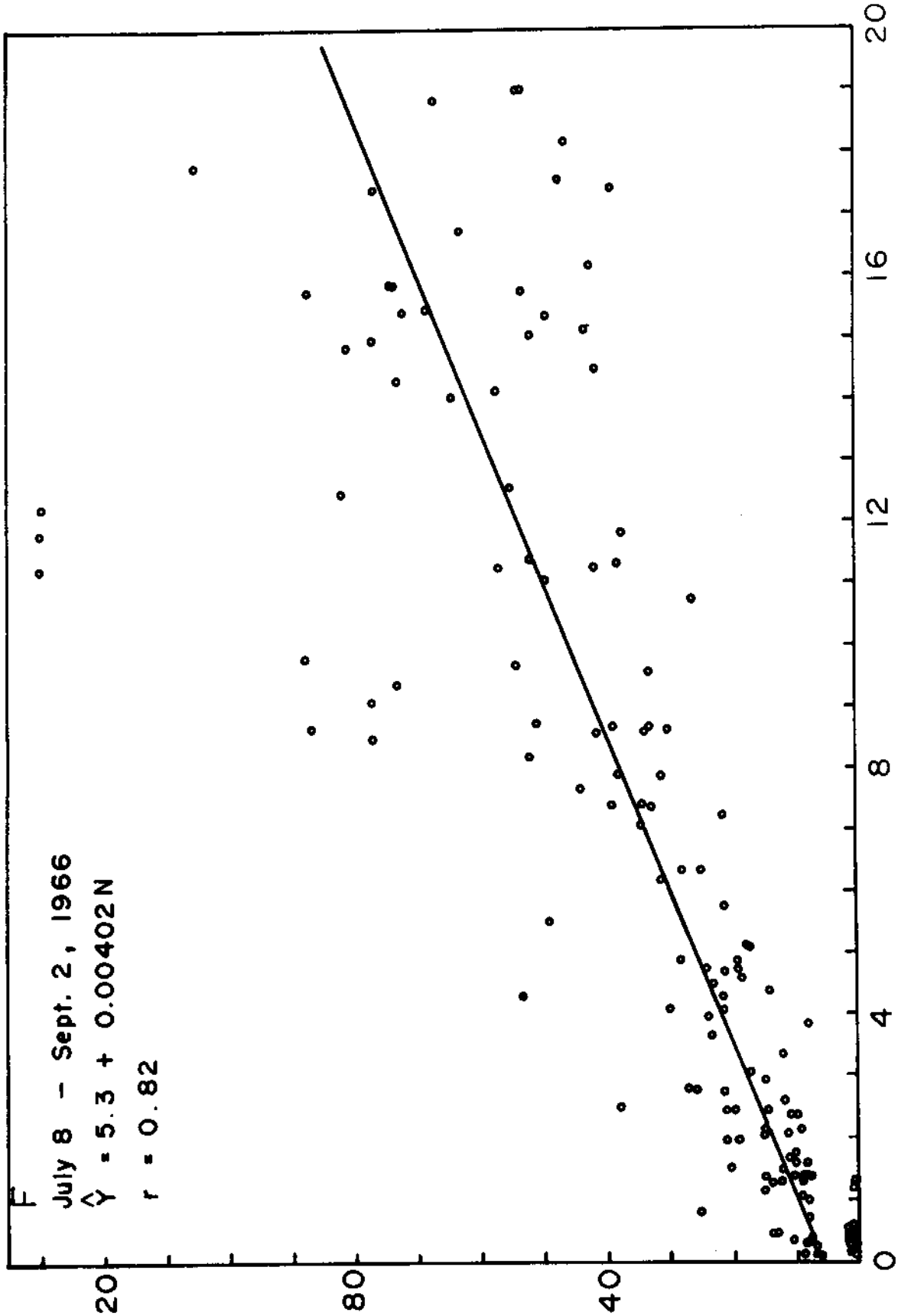
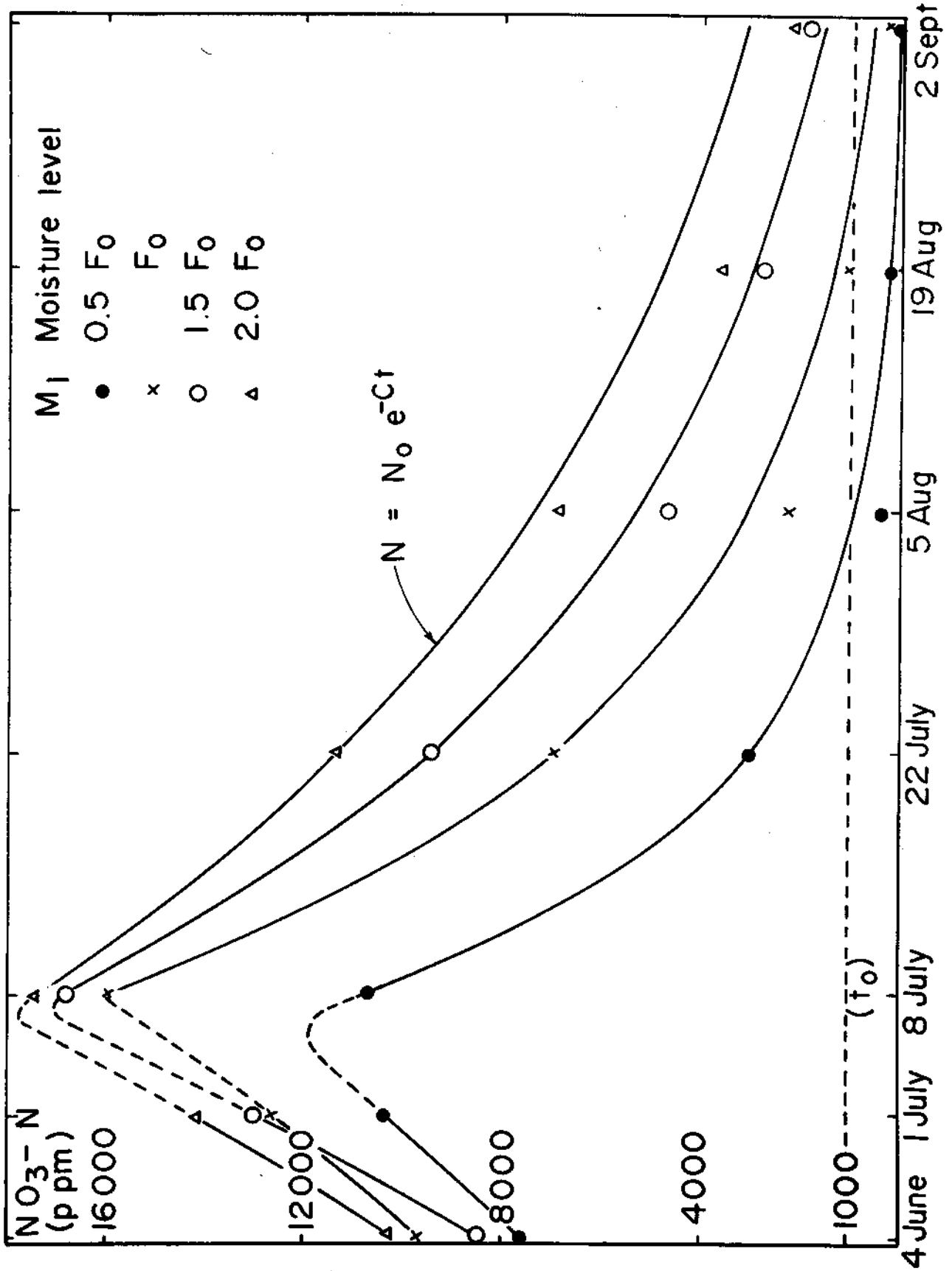


Figure 2. Comparison between a quick-test on the fresh tissue (F) and a laboratory analysis on the dried, ground petioles for NO_3-N(N) concentration in sugar beet petioles.



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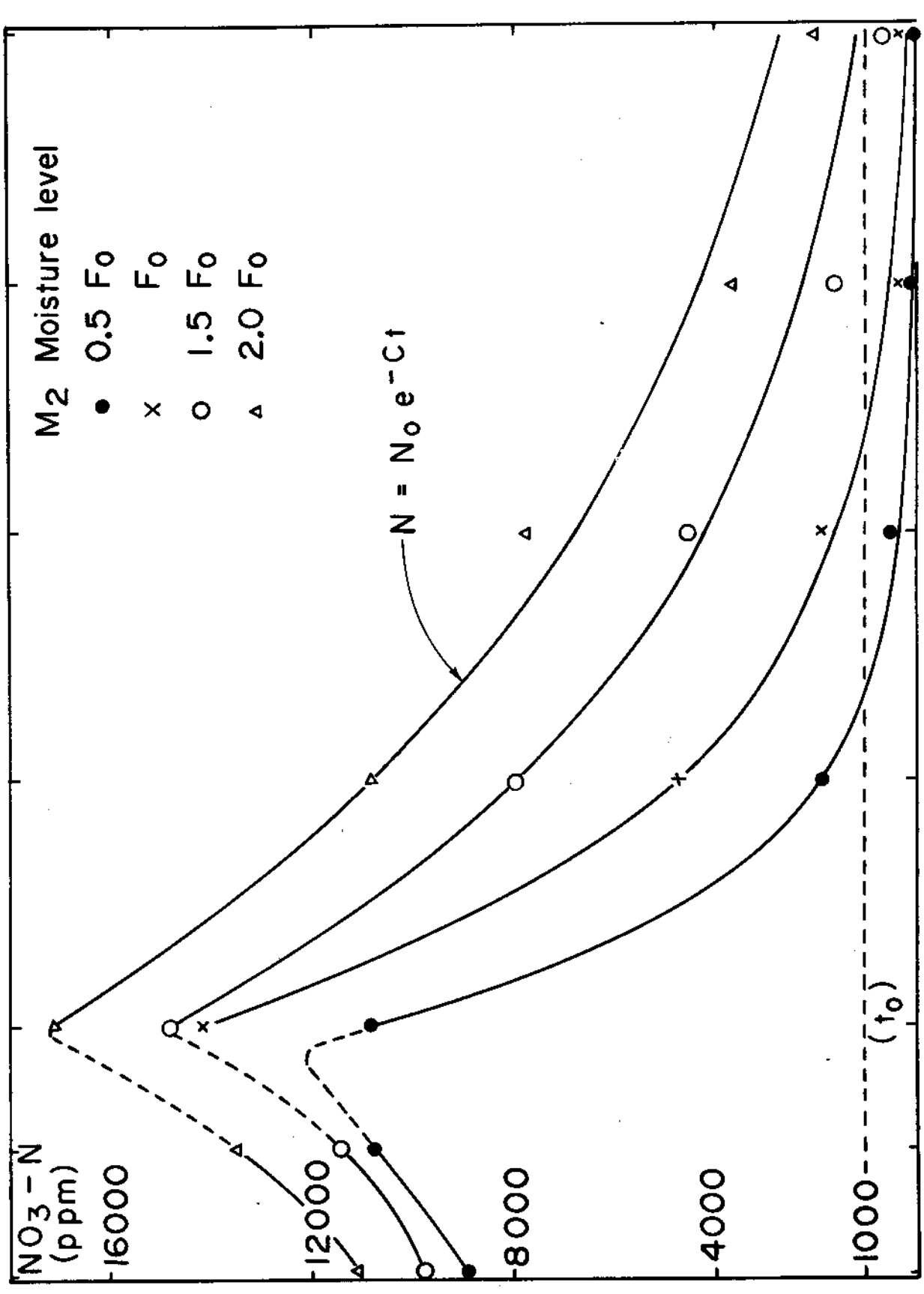

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